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Research funding programmes aiming for societal transformations: ten key stages

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Abstract

Societal issues such as poverty, water scarcity, and food insecurity make it more important than ever for science to produce knowledge that is relevant to address serious challenges on the ground. A growing number of research funding programmes emphasize the need for transdisciplinary (TD) co-production of knowledge as one way of making research part of needed societal transformations. Despite this positive trend, very few studies have focused in particular on how research *funding* programmes themselves could enhance the implementation of TD research. To address this gap, we explored processes and structures of TD research funding programmes, and created a generic model that explicitly shows the key stages relevant to the enhancement of TD research. Based on a discussion of these key stages with representatives of four TD research funding programmes we co-produced design recommendations that offer guidance for implementation of future programmes.

Key words: transdisciplinary; research funding programmes; research management; societal transformations; design recommendations

1. Introduction

Societal challenges such as poverty, soil degradation, water scarcity, and food insecurity make it more important than ever for science to produce evidence-based knowledge capable of tackling concrete problems and aiding wider societal transformations. But how, specifically, can science support transformation of these societal challenges? And what kinds of knowledge and knowledge-production processes are relevant? An increasing number of research programmes and funding bodies—such as the international Future Earth initiative, Europe's Horizon 2020 programme, the Swiss National Research Programmes (NRP), the International Council for Science (ICSU), and the International Social Science Council (ISSC)—answer these questions by calling for transdisciplinary (TD) approaches of knowledge co-production. TD research is considered a promising approach because it focuses on societal challenges and integrates knowledge from different scientific disciplines and societal actors (de Jong et al. 2016; Dedeurwaerdere 2013; Hirsch Hadorn et al. 2008; Lang et al. 2012; Mitchell et al. 2015).

However, while there is an increasing body of literature about TD research at the project level (Schneider et al., 2013) (Wiek et al. 2012) (Renner, 2013) , very little research has focused more specifically on how different structures of overall *research funding programmes* relate to successful enhancement and implementation of such research (Lyall et al. 2013). In order to address this gap and advance the potential of research funding programmes to foster societal transformations via TD research, this article introduces a generic model and design recommendations for TD research funding programmes, developed jointly with key actors.

In the following, we will discuss research programmes that: (1) aim to develop contributions that help alleviate societal challenges; (2) assume that doing so requires TD co-production of knowledge and collaboration between academic and societal actors; and (3) seek to work towards a synthesis and (re-) integration of programme results into societal practices to contribute to societal transformations.

Before presenting the methodology and our results in Sections 2 and 3, the following section introduces the relevant TD literature focusing on design principles, societal transformations, and the role of science policy.

1.1 The significance of TD research for societal transformations

There is growing agreement that traditional ways of disciplinary knowledge production are no longer sufficient to address societal challenges. In contrast to many disciplinary problems, societal

challenges are highly complex, contested, and their development is often uncertain (Huutoniemi 2014; Pahl-Wostl 2002). They often include complex interrelationships between sociocultural, economic, and biophysical dimensions, and their causes and consequences can be distant in time and space. Moreover, various key societal actors may have differing and even conflicting views on what societal problems are most relevant and what transformations are required. This 'wickedness' of societal challenges has important epistemological implications for research (Huutoniemi 2014; Leach et al. 2010; Pahl-Wostl et al. 2007), since scientific knowledge cannot be regarded as the only possible truth.

Consequently, researchers seeking to address societal challenges have developed novel approaches to knowledge production such as TD research (Hirsch Hadorn et al. 2006; Jahn et al. 2012; Klein 2001; Pohl 2008; Wiesmann et al. 2011), including 'Mode 2' research (Nowotny et al., 2001) and 'action research' (Reason and Hilary, 2001). What these approaches have in common is that they seek to accommodate the complexity, uncertainty, and contested nature of current societal challenges as well as to contribute to their transformation. In these approaches, scientific knowledge is perceived to be part of its wider societal, cultural, historical, and 'natural' environments rather than somehow independent of them.

We position our article in the field of TD research—a research approach that we distinguish as follows: First, it is a collaborative mode of knowledge co-production that is oriented towards specific societal challenges and integrates knowledge and perspectives from different scientific disciplines and other societal actors. Secondly, it produces not only *systems knowledge* (analytical or descriptive knowledge about specific societal problems), but also *target knowledge* (normative knowledge about values and norms related to a more desirable future) and *transformation knowledge* (practical knowledge about how to transform an existing problematic situation into a better one). Finally, it is viewed as part of an overall societal learning process geared towards societal transformations of existing challenges (Hirsch Hadorn et al. 2008; Pohl 2011).[1]

By societal transformation, we mean an emancipatory process of structural change involving alterations of worldviews, values, agency, power relations, social networks, ecosystems, and physical infrastructure (Feola 2015; O'Brien 2012) necessary to reshape the concerned societal challenge into a more desirable future.

1.2 TD process principles and transformation impacts

In recent years, academics have sought to develop theories, methods, approaches, quality criteria, and principles that serve to establish TD research as a scientific mode of knowledge production (Bergmann et al. 2005; Jahn et al. 2012; Lang et al. 2012; Pohl and Hadorn 2007). In an influential article summarizing different research endeavours, Lang et al. (2012) present a conceptual model of an ideal-typical TD research process. They describe this process as composed of a sequence of three phases: Phase A, 'collaboratively framing the problem and building a collaborative research team'; Phase B, 'co-producing solution-oriented and transferable knowledge through collaborative research'; and Phase C, '(re-)integrating and applying the produced knowledge in both scientific and societal practice'. For each of these phases, they identify specific design principles, in particular the importance of collaboration between researchers and societal actors throughout the whole TD research process; careful design of collaborative methods; and production of targeted knowledge products.

More recently, an increasing body of research has begun to stress the societal impact and transformation dimension of TD research, which was often taken for granted in earlier approaches (de Jong et al. 2016; Grunwald 2015; Schneidewind and Mandy 2013). Various researchers recommend explicitly defining desired goals of societal transformation—not only research goals—at the start of the research process, since this has profound implications for the design and evaluation of TD research (de Jong et al. 2016; Mitchell et al. 2015).

1.3 The role of science policy for TD research

As the field of TD research has developed, many scholars have pointed out how the prevailing research context shaped by current science policy[2] is persistently unfavourable to TD modes of knowledge production; TD requires conditions that differ from those needed for basic disciplinary research (Dedeurwaerdere 2013; Kläy et al. 2015; Kueffer et al. 2012; Schneidewind 2009). For example, implementation of TD research requires time, skills, and resources for collaborating with other disciplines and societal actors throughout the research process. This process must include efforts towards joint problem framing, exploration of goals and pathways to societal transformations, and co-production and communication of knowledge with and to non-scientific actors. In addition, evaluation of the quality and impact of TD research demands criteria that do justice to the TD character of the project (Roux et al. 2010).

Research funding bodies increasingly acknowledge the importance of TD research, yet their management, evaluation, and funding practices often do not reflect this (Woelert and Millar 2013). For example, there is much evidence that interdisciplinary and TD research proposals have difficulty obtaining funding, since reviewers typically apply disciplinary perspectives and quality criteria instead of considering the integrated whole (Bromham et al. 2016; Mansilla 2006; Woelert and Millar 2013). Moreover, (classic) academic careers are still typically built on measuring scientific impact according to publication in peer-reviewed journals—journals that are more interested in the scientific part of TD research, not in the efforts of such research to contribute to actual societal transformations (Kueffer et al. 2012; Rhoten and Parker 2004). Consequently, for TD research to reach its full potential, experts argue that far-reaching structural and institutional changes are needed in the way academic organizations are managed, organized, and funded (Dedeurwaerdere 2013; Kläy et al. 2015; Kueffer et al. 2012; Schneidewind 2009).

With third-party funding increasingly required for research, research funding programmes and bodies now play a crucial role in science policy (Braun 1998; Bromham et al. 2016; Lyall et al. 2013) and, consequently, in possible changes to the science policy context. Funding bodies strongly influence what kind of research

1 The present definition of TD is most common in Europe, particularly in German-speaking countries. It goes beyond the notion of interdisciplinarity, which we understand as a research mode integrating different scientific disciplines (but not necessarily other societal, non-academic actors). Nevertheless, some authors, particularly those from Anglo-Saxon and French-speaking countries, use the term transdisciplinarity for what we would call interdisciplinarity. Further, it is important to note that TD research is not simply about better communicating science, but is rather, in essence, a different mode of knowledge production (Roux et al. 2006; Pohl et al. 2010; Pohl 2011) that seeks to contribute to societal transformations.

2 Science policy concerns research funding, the career pathways of scientists, and organization of the science–society interface.

programmes get launched, what research proposals get funded, what kinds of impacts are valued, what networking and capacity-building opportunities are possible, and what sort of career experience is considered valuable in applicants for funding.

1.4 How can TD research funding programmes become more effective?

In recent years, an increasing number of research funding bodies have been implementing entire funding programmes dedicated to addressing diverse societal challenges by means of TD approaches (Hoffmann 2016; Lyall et al. 2013; Wardenaar 2014). However, the people responsible for these programmes often face challenges in designing and implementing structures and processes that enable TD knowledge production *at the level of an overall research funding programme* (Lyall et al. 2013). Indeed, to date, very little documented experience exists in implementing TD research at the programme level, and very few scientific studies have examined such programmes beyond a focus on individual activities (Bergmann et al. 2005; de Jong et al. 2016; Defila and Di Giulio 1999; Klein 2008; Pohl 2011; Roux et al. 2010).

A valuable exception is the work of Lyall et al. (2013), who investigated the role of funding agencies in creating TD knowledge[3]to promote learning and practical guidance to funders. The researchers identified the following key success factors: identification of the appropriate loci of TD, knowledge integration as deliberate steps throughout the programme, inspiring leadership, active management, learning, and continuity. Moreover, they highlighted the following key aspects for consideration by funding bodies: shaping TD research initiatives, reviewing and evaluating TD research appropriately, building TD capacity, encouraging stakeholder engagement, and ensuring the sustainability of interdisciplinary research.

In addition, several scholars have investigated the *management* of large TD research programmes (Defila et al. 2006; König et al. 2013)—though without necessarily focusing on funding-related activities specifically. In their look at management, for example, Defila et al. (2006) emphasize that TD collaboration does not occur automatically, but rather must be purposefully initiated, moderated, and accompanied. Further, they observe that the management of TD research programmes must be professionalized, and the people managing these programmes must be supported. In their detailed handbook for programme managers, they identify eight main tasks and recommend their implementation in different project phases: (1) joint goals and questions; (2) integration of research networks; (3) synthesis; (4) joint products; (5) selection of persons and team building; (6) involvement of external actors; (7) internal and external communication; and (8) organization of work.

Our article contributes to these debates by investigating how large research funding programmes can support and implement TD research more effectively. With the term 'TD research funding programme', we mean funding programmes whose basic parameters are predefined. They are generally launched by a funding body with the goal of financing research on a specific topic or conceptual issue. They embrace several independent research projects with their own sub-goals and methods. However, all involved projects are generally expected to contribute to the overall programme goal(s).

3 Catherine Lyall et al. (2013), 'The Role of Funding Agencies in Creating Interdisciplinary Knowledge', *Science and Public Policy,* refer to 'interdisciplinary knowledge' in their article, but their definition appears to be very close to our concept of TD knowledge.

2. Materials and methods

2.1 Research context and case study

Our study is based on an investigation of TD research-funding programmes in Switzerland. The Swiss National Science Foundation (SNSF) is the main Swiss institution promoting scientific research. It has a long tradition of supporting application-oriented, thematic research programmes, but only recently began supporting TD research more specifically (Häberli and Grossenbacher-Mansuy 1998). For few years, TD has been an explicit requirement of the SNSF's National Research Programmes (NRPs), and the Swiss Programme for Research on Global Issues for Development (r4d programme). The latter programme is jointly funded by the SNSF and the Swiss Agency for Development and Cooperation (SDC). The Swiss National Centre of Competence in Research (NCCR) North-South programme may be considered a forerunner of these TD programmes.

While science in Switzerland generally remains dominated by disciplinary research, TD approaches have become an important niche: Swiss researchers developed key theoretical and practical contributions to the emerging international TD community (Defila et al. 2006; Hirsch Hadorn et al. 2008; Pohl 2008; Scholz et al. 2006; Wiesmann et al. 2011). Hence, when establishing the TD-funding programmes, SNSF benefited from the extensive TD expertise available in Switzerland, in particular the work of the Commission for Research Partnerships with Developing Countries (KFPE) and the Network for Transdisciplinary Research (td-net), both belonging to the Swiss Academies of Arts and Sciences.

Our research builds on the experiences of each of these SNSF funding schemes (NRP, NCCR, r4d programme). Table 1 provides an overview of the specific funding programmes involved in this study.

2.2 The methodological approach

Crucially, in our investigation of how research funding programmes can support and implement TD research more effectively, we ourselves adopted a TD research approach (Hirsch Hadorn et al. 2008; Lang et al. 2012). A TD approach is highly suited to generating actionable knowledge on this issue because it combines rigorous scientific thinking and analysis with the knowledge and experiences of the actors involved (Adler et al. 2009; Nowotny et al. 2001).

A key component of the TD methodology was a 'learning group' representing different positions and experiences regarding implementation of TD research funding programmes. A learning group is a group of actors who regularly come together to share knowledge and experiences, and to co-produce new knowledge needed to improve the quality or effectiveness of practices serving a specific goal. In contrast to social science methods like focus groups, the researchers and other societal actors in the learning group seek to produce the new knowledge together, and co-design the overall process, including goal definition and workshop setting.

The group was initiated and facilitated by the co-authors and comprised coordinators, knowledge exchange experts, and participating researchers, from the four SNSF-funded TD programmes as well as TD experts from KFPE, the td-net, and dialogue4change (20 participants in total). The participation criteria were as follows: (1) interest in mutual, self-reflective learning aimed at enhancing the

Table 1. Overview of the four research funding programmes involved in the study

	NRP 61	NRP 68	NCCR North–South	r4d programme
Title	Sustainable Water Management	Sustainable Use of Soil as a Resource	Research for Mitigating Syndromes of Global Change	Swiss Programme for Research on Global Issues for Development
Duration	2010–2014	2012–2018	2001–2013	2012–2021
Projects and phases	16 projects	21 + 4 projects	8 + 13+21 projects	3 + 4+5 + 4+4 + 24 projects
	1 phase	2 phases	3 phases	5 thematic modules and 1 thematically open module
Programme goals	Generating praxis-relevant knowledge in the area of water resources and management	Improving knowledge about soil systems, developing tools for assessing soil as a resource, and devising concepts for a sustainable use of soil	Mitigating syndromes of global change through research, capacity building, and empowerment	Supports research aimed at solving global problems with a focus on least-developed, low- and middle-income countries
Programme development	Topics suggested by societal actors; decision on topic made by the Swiss Federal Council; preparation of call and implementation by SNSF; applicants submit proposals and SNSF selects projects		SNSF launched an open call; topics and implementation plan were suggested by applicant universities; SNSF proposed selection of topics to the Federal Administration; funding decision made by Swiss parliament; additional third-party funding by SDC; applicants decided about project-selection procedures	Topics and general programme concept defined by SDC and SNSF; implementation by SNSF; applicants submit proposals and SNSF selects projects
Programme- level activities	Programme coordination and steering, launch of calls, project selection, monitoring and reporting, skill development and knowledge-exchange events, external and internal communication, synthesis			
TD meanings	Involvement of practitioners and interdisciplinarity, practice-relevant knowledge		Transnational research partnerships, empowerment of Southern partners, joint learning processes, pathways to impact	
TD features	Mix of disciplinary and TD projects; synthesis partly TD; synthesis and self-reflection on TD	Mix of disciplinary and TD projects; synthesis mostly TD	Mostly TD projects; implementation projects were integrated; synthesis partly TD; synthesis and self-reflection on TD	Mostly TD projects; small implementation projects are integrated; synthesis and self-reflection on TD
Objective of funding scheme	Directing and supporting coordinated research projects that have a common goal and contribute to the solution of contemporary problems of national importance. NRPs are distinguished by the following characteristics: solution orientation, practical relevance, interdisciplinarity and TD, knowledge transfer		NCCRs promote long-term research networks in areas of strategic importance for Swiss science, the Swiss economy, and Swiss society	Ditto programme goal
Funding	SNSF: CHF 12 million	SNSF: CHF 13 million	SNSF, SDC, UniBE: CHF 36 million	SNSF, SDC: CHF 97.6 million
Further information	www.nrp61.ch	www.nrp68.ch	www.nccr-north-south.unibe.ch	www.r4d.ch

quality of TD; (2) innovativeness and experience with TD work, whether at the project, programme, or policy level; and (3) involvement in an ongoing or recently finished TD research funding programme. The group met in a series of three half-day workshops, which were systematically documented and audio recorded.

To address the overall research question, we found it necessary to construct a conceptual model of TD research funding programmes, since they involve more stages and activities than TD research projects. Development of the model was based on participatory modelling techniques (Vennix 1996; Voinov et al. 2016), which incorporate the perspectives and experiences of potential knowledge users in the process of model construction. The iterative process encompassed joint conceptualization, formalization, and verification through empirical insights.

Our *conceptual* starting point was the Lang et al. (2012) model of TD research. Our *empirical* starting point was NRP 61, which we adopted as an in-depth case study. Importantly, NRP 61 was one of two programmes whose TD processes were assessed previously (Hoffmann et al. 2017; Rist 2014; Schneider and Buser 2018). Next, to continuously validate and further conceptualize the evolving TD programme model, we considered and tested findings regarding structures and processes from the other three programmes as well as

insights from the literature (Defila et al. 2006; Lyall et al. 2013; Roux et al. 2010; Stöckli et al. 2012). By doing so, we identified key stages step by step that appeared to be instrumental to successful implementation of the TD programmes. For example, when discussing challenges in TD synthesis of NRP 61 (later identified as Stage 7) and considering the experiences of other programmes, we realized that the observed challenges might relate to earlier programme phases. In particular, we noted the absence of a stage in which to jointly formulate problems and goals, with the result that individual project goals did not fully match the programme goals. By reflecting on the positive experiences of the NCCR North-South programme in organizing workshops, we concluded that joint agenda setting (later Stage 6) is an important activity of TD research funding programmes.

Three distinct participatory modelling cycles were initiated by an input of the co-authors (e.g. the first draft of a model, or analysis of programme structures), and then critically discussed by the whole group. The co-authors then revised the previous work to prepare a new version reflecting the views of the participants. Moreover, to increase the evidence base, they conducted additional research on the issues discussed, presenting the results at the next group meeting.

The additional research included document review of all four relevant programmes, and secondary analysis of 18 semi-structured interviews with representatives of NRP 61 (i.e. research project leaders [16], the programme's president, and its knowledge-exchange expert), who were part of earlier research by Schneider and Buser (2018). Document review of programme calls, proposals, implementation plans, and stakeholder engagement concepts made it possible to systematize the programme activities, phases, and management stages comprising the architecture of the TD programme model. Qualitative content analysis (Flick 2005) of interview transcripts and programme reports (Hoffmann et al. 2017; Michel et al. 2013; Claudia Michel et al. 2014; Rist 2014; Schneider and Buser 2018) provided further insights into potentials and challenges experienced by the actors involved. Hence, these steps substantiated the identification of key stages of TD programme implementation and the development of design recommendations.

For more details on the overall methodological approach—including workshop organization and intermediary steps of the modelling process—see Appendix 1–3.

6.3 Context of the TD Collaboration

The research described in this article belongs to a larger process aimed at jointly developing a new research proposal based on extensive reflection on implementation experiences of two pioneering, recently completed TD research programmes: NRP 61 and the NCCR North-South. The co-authors were involved in previous TD evaluations of both programmes (three authors with the NRP 61; one with the NCCR North–South; one new). Hence, they had existing work relations with key actors and had already discussed with them some challenges of implementing TD research funding programmes. The project was financed by the Sustainable Development at Universities Programme (SUK), which supported projects in developing TD research proposals based on participatory problem framing with all actors involved.

The initial idea was to build a learning group of representatives of the two programmes (coordinators and researchers) and TD experts to jointly frame relevant problems and goals for a new research project. The perspectives of other involved stakeholders were to be integrated through interviews (in-depth case studies of six TD research projects in total, three from each programme). Participants' motivations for joining the group were heterogeneous: While all shared a concern for the topic and wanted to engage in self-reflective learning, coordinators were particularly interested in learning from other programme experiences, and researchers wanted to gain insights into how the stakeholders involved in their projects perceived the TD collaboration.

Discussions at a first scoping workshop of the learning group confirmed the importance of the topic, but led to suggestions for changing the initial project idea. The participants found that it would be more interesting to focus on the level of overall TD research funding programmes, instead of particular TD research projects or stakeholders' perspectives. Overall, they identified various TD-relevant science policy challenges as the real-world problem they wanted to focus on. For example, researchers stressed that existing science policy structures are not always favourable to TD, and programme coordinators highlighted the challenges of designing more favourable programme structures and processes within the existing policy context. The lack of a suitable model of TD research funding programmes and respective design principles were cited as the main scientific problem to be addressed.

As a consequence, the group agreed to cancel the planned case study research on TD projects in favour of an analysis of TD research funding programmes, in particular the NRP 61. This change in focus also brought about changes in the group's composition: some researchers lost interest in participating, while other ongoing TD programmes wanted to join (NRP 68, r4d programme, Future Earth).

The results presented in this article are based on the first three workshops of the group. The group continued to meet afterwards and several members are currently collaborating on a new jointly acquired research project.

3. Results

3.1 Conceptual model and key stages of a TD research programme

Our generic model conceptualizes a TD research funding programme in three overlapping phases, with three levels of programme activities, and 10 key stages of TD interaction (for an overview and details on how they relate to each other, see Fig. 1).

Three overlapping phases are (1) problem and goal definition, (2) co-production of new knowledge, and (3) contributions to societal transformations.

As proposed for research projects (Hirsch Hadorn et al. 2008; Lang et al. 2012), a research programme can be structured between three phases: problem and goal definition (Phase A), co-production of new knowledge (Phase B), and contributions to societal transformations (Phase C). These phases are overlapping in the developed model; this is meant to highlight that they do not follow each other in a linear way, but are instead iterative or even represent recursive cycles.

There are three levels of programme activities. They are (1) programme navigation, (2) project support and (3) project implementation.

Programme navigation. Programme navigation comprises all activities that are involved in planning, managing, governing, and implementing TD knowledge production at the level of the overall programme. It also involves synthesis processes for the achievement of overall programme goals.

Project support. TD research programmes usually offer different kinds of support to their projects: funds, information, advice, training, etc. With these support activities, they can ensure and enhance the quality of TD work in their research projects.

Project implementation. A TD research programme generally comprises a set of several more or less independent research projects, which conduct TD research addressing a programme sub-theme in a specific context.

3.2 Ten key stages for TD interaction

Our collaborative research showed that in the course of a TD research funding programme, 10 key stages are relevant to enable successful TD research. Problem and goal definition (Phase A) occurs in Stages 1, 2, 3, 4, 6 and 8; co-production of knowledge (Phase B) in Stages 5, 7, 8; and contributions to societal transformations in Stages 9 and 10 (and, in part, 8). In the following, we will introduce the stages sequentially; however, as noted above, they may actually overlap or reoccur in a cyclical manner. As we mainly focused on the activities and stages that funding bodies and programme managers can influence, we do not present details or recommendations regarding project implementation (Stages 2 and 5).

To illustrate what can be done not only to implement these stages in a beneficial way, but also to show what kinds of challenges can occur in a specific programme, we present details of the activities and experiences of NRP 61 in Table 2.

1. *Programme preparation (Phase A, programme navigation)*. The first key stage involves the preparation of the programme description. In this stage, the overall parameters of future research are set. This program description provides an initial outline of the relevant societal problems, goals, and research questions, as well as available funds. Moreover, by outlining the general research requirements, it also determines the room for manoeuvre applicants will have in designing and implementing TD processes within specific projects. In most cases, the programme preparation includes a formal call for projects. As such, basic aspects of problems and goals are defined by actors who will not be directly involved in the eventual research projects (e.g. the NRPs). In other cases, it takes the form of a proposal elaborated by the eventual researchers (e.g. the NCCRs).

   Considering the importance of the programme preparation phase in defining the scope of the programme, group members stressed that in a TD programme open dialogues must exist from the very beginning to facilitate mutual understanding and joint definition of problems and goals, in particular, with societal actors. At the same time, they mentioned that certain goal formulations can and should be left somewhat open to allow for later concretization through the grantees (see Stage 2). The latter is also important to enable reframing of programme goals based on the final composition of selected research projects (see Stage 6).

   Moreover, when aiming to contribute to societal transformations through the programme, our research highlighted the importance of formulating not only the thematic topics to be addressed in research (scientific goals), but also the societal transformation goals, as well as the methods and pathways/processes to enable such contributions. In addition, programme frameworks should be defined such that they enable favourable conditions for TD research (see all following stages).

2. *Proposal elaboration (Phase A, implementation of projects)*. In response to the programme call, research consortiums then write and submit TD research project proposals specifying particular goals, research questions, and methodological approaches. They take into account the requirements and framings of the call, but also typically add new framings that represent their own problem perceptions and interests, as well as those of the societal actors they collaborate with. As a consequence, developed research proposals might not cover all goals mentioned in the programme call.

   The research also revealed that TD consortiums usually require a generous amount of time to frame problems and goals, since they must first reach mutual understandings about societal and scientific knowledge gaps and priorities. This is especially the case when participating actors have no prior relationship and trust must be built.

   Research funding programmes can tackle these challenges through activities proposed in stages 3, 4, and 6.

3. *Interactions with applicants (Phase A, project support)*. Emphasizing the competitive character of the tender process, programme-level actors usually limit their interactions with applicants to clarification of formal requirements, as well as decision letters in case of two-step evaluation procedures. But as the experiences of our learning group members revealed, applicants are often unclear as to what is expected of them and what they can apply for. Moreover, considering the dominance of disciplinarily education in academia, skills and competences in TD research are still limited among applicants. Hence, group members observed that research funding programmes can considerably enhance the TD quality of the proposals and ultimately the overall programme by supporting the applicants in the proposal writing stage. This support can range from clear communication of call requirements regarding TD and offering preliminary feedback in the case of two-step evaluation procedures up to and including ensuring adequate time and funding (e.g. by providing seed money for TD problem framing), and arranging training in TD methods[4]. Moreover, the design recommendations that were identified for Stage 8 (interactions with participating projects) are also relevant for this very early interaction with applicants.
4. *Project selection (Phase A, programme navigation)*. In this stage, the programme evaluates the proposals and decides which projects will be included in the programme, what is expected of them, and how much funding they will receive. This stage is a key in a TD programme, as it determines the final programme composition, including the involvement of all relevant thematic sub-topics and TD competences, as well as the provisioning of adequate funding of TD work.

   Thus, in the selection stage, group members highlighted that projects should be chosen that contribute to the programme's defined scientific goals *and* to its intended societal transformation goals. In addition, consideration should be given to innovative ideas proposed by applicants. But it was also stressed that research programmes should begin by optimizing the framework conditions in which research projects operate to

4 The latter two suggestions were not implemented by our four programmes, but by other programmes in which group members were involved, e.g. the Swiss Sustainable Development at Universities Programme (SUK), and the LIRA 2030 Programme of ISC (formerly ICSU).

Table 2. Example: activities and experiences of the TD Swiss National Research Programme (NRP 61) 'Sustainable Water Management', structured according to the 10 key stages of TD interactions

Key stages	Approaches and experiences of NRP 61
1. Programme preparation	In a formal process, various societal actors—including federal offices, research institutes, and NGOs—proposed water as a topic for a new NRP. The Swiss Federal Council made the final selection of the topic, based on a programme outline elaborated by SNSF. After this decision, the appointed programme president wrote a programme call together with the steering committee. While societal actors had some say in defining the general programme topic, there was relatively little societal involvement in the final definition of specific programme goals and requirements.
	The selection criteria defined in the programme call emphasized scientific quality, interdisciplinarity and TD, compliance with programme goals, and a focus on application and implementation.
2. Proposal elaboration	Project applicants interpreted the programme call in different ways and integrated societal actors to differing degrees. Some built consortiums with scientific and societal actors, while others organized a joint workshop to identify the most-relevant research topics before finalizing the proposal. The majority defined societally relevant questions based on their research experience without explicitly consulting societal actors.
3. Interactions with applicants	Project evaluation was a two-phase process (pre-proposals and full proposals). The requirement of TD was clearly communicated in the call, and applicants were expected to document societal actors' involvement in the problem framing and the planned research. In some cases, projects were asked to improve their TD designs and societal relevance after their pre-proposals were evaluated.
4. Project selection	Evaluation and selection were conducted by a steering committee supported by external reviewers. The head of knowledge exchange with expertise in TD and a representative of the Federal Administration each had advisory roles. Other than this, non-academic societal actors were not involved.
	Programme representatives reported that the thematic orientation of the submitted proposals did not fully cover all the intended programme subtopics. Moreover, comparatively few proposals demonstrated sound TD competences and research designs. All in all, less than half of the selected project teams were experienced in TD. However, those applying TD designs could receive funding for senior researchers dedicated to TD work.
5. Research activities	Individual projects varied widely in their intensity of TD collaboration. Projects ranged from rather elementary one-way communication designs to sophisticated TD designs aiming at knowledge co-production on equal footing from start to finish.
	In this stage, most of research projects became very caught up in their specific research questions. Programme goals were relegated to the background and only identified with to a limited extent. Consequently, many rather disciplinary projects found it difficult to grasp what TD would mean and why they should engage in synthesis activities.
6. Joint agenda setting	After project selection, the steering committee adjusted the programme's thematic lines according to the topics of the selected projects. However, many of the projects were not satisfied with their assigned roles and expected contributions. In response to the demand of project teams, the steering committee initiated an ad hoc bottom-up process to define priority topics, which would be expected to bundle the communication of research results to society. The advisory group comprising societal actors was invited, but very few of them wound up playing an active role.
	Overall, the importance of this stage was underestimated from a TD perspective. There was no agreed-upon strategy of how to come up with a coherent set of priority topics that would integrate the programme goals as well as the goals of the individual projects. Consequently, many research projects resisted TD collaborations towards achieving the programme goals.
7. Networking and integration	Diverse networking opportunities were organized including annual programme meetings. Knowledge exchange between the involved projects and societal actors was also facilitated through creation of 'social learning videos' on the research of individual projects. Synthesis work was conducted by synthesis teams composed of project researchers and societal actors according to four different thematic lines. Additional funding made the synthesis work possible. The synthesis process was challenging due to people's differing expectations of the process and the leadership.
8. Interactions with participating projects	Projects were required to report about their TD work as part of their annual reporting. The head of knowledge exchange visited each project and offered advice. A workshop was organized about TD research.
	Research projects involving seniors experienced in TD knowledge production were very satisfied with these support offerings. However, less experienced research projects felt they did not receive enough support in integrating TD into their specific research. They expressed dissatisfaction, for example, about insufficient feedback on their TD efforts; at the same time, they rarely requested such advice. Very few projects were aware that they could request additional funding for TD activities from the programme.
9. External communication and implementation	The head of knowledge exchange developed a comprehensive communication and implementation concept that was continuously adapted throughout the programme. Each project was expected to engage in communication and implementation activities. The programme supported them in creating videos for communication with societal actors, as well as in preparing practice-oriented articles for professional journals. At the programme level, thematic synthesis booklets were produced and public events were organized, with the latter including workshops with practitioners and a touring exhibition.
	A limited structured debate was held with all the research-programme actors about envisioned societal transformations, stakeholders involved, and methods that would enable achievement.
10. Programme conclusion and evaluation	The programme concluded with two major communication events, including a marketplace for practice-relevant insights. Afterwards, a handful of activities continued, such as the touring exhibition.
	Several researchers felt that four years was not enough time to maximize their research results vis-à-vis TD. Several projects reported, for example, that development of trust with local actors required more time and that more interactions would be needed to explore opportunities for implementation of the new insights they elaborated. Others reported that they had enough time to better understand a situation, but that more time would be needed to create an applicable tool.
	The progress and impacts of the projects were monitored by means of annual reporting. Two assessments were conducted towards the end of the programme to learn about the overall programme experience with TD research: one assessment focussed on the process of synthesis building (Hoffmann et al., 2017); the other focussed on the involvement of societal actors in the participating projects (Schneider and Buser, 2018). An impact assessment is currently slated to occur two years after conclusion of the programme.

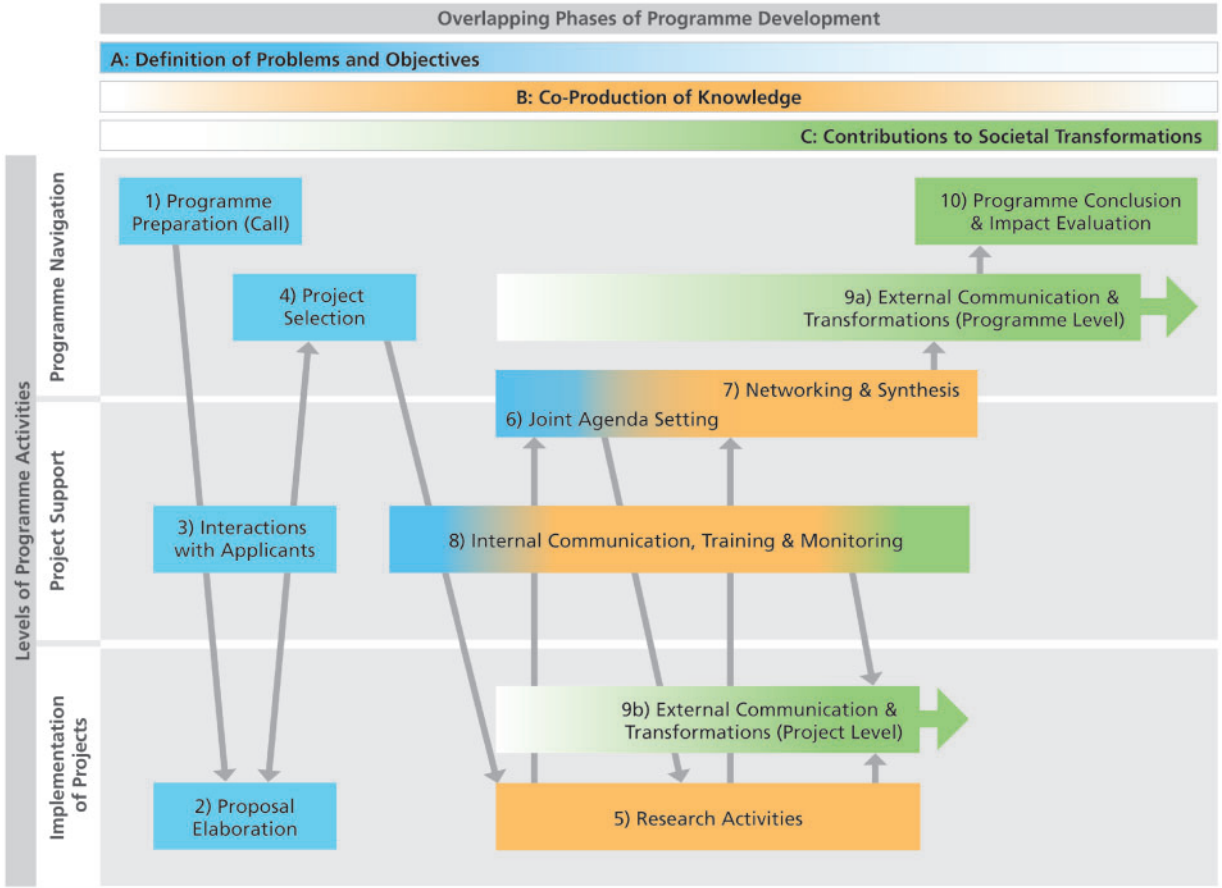

Figure 1. Conceptual model of a TD research funding programme involving 10 key stages (the width of symbols represents the relative importance of the stages over time).

support their TD endeavours. For example, it showed to be crucial to ensure funding of experienced senior researchers and process facilitators who are capable of moderating processes of knowledge co-production and overseeing integration of different types of knowledge. Projects based mainly on PhD research can hardly fulfil the demanding work of TD collaboration due to lack of time, experience, and seniority. It should go without saying that TD work requires its own budgetary allowance and should not be regarded as a free addition. Funding of transformation and follow-up processes often turned out to be required later to bring research results to fruition. However, it was also stressed that if TD designs and efforts appear insufficient, the programme should ask the projects to make improvements to demonstrate that TD is taken seriously.

Our comparison of different programme approaches revealed three basic strategies for selecting projects: (1) selecting a set of individual projects, in which each project applies a systematic TD and transformation-oriented approach while addressing a sub-goal of the programme; (2) selecting a suitable mix of rather disciplinary projects, in which the programme goals are addressed by means of TD synthesis efforts at the programme level; (3) selecting projects that result in a combination of the first two strategies. In the first strategy, decisions about project approval should consider the TD quality of each project proposal and the TD competences of all applicant teams. In the second and third strategy, not every research project must be designed in a fully TD way; however, the composition of selected projects must be appropriate and TD process knowledge must be assured at the programme level.

Whatever the case, in selecting research projects, TD research programmes must apply evaluation criteria and procedures that do justice to the TD character of research proposals.

5. *Research activities (Phase B, implementation of projects)*. With the official start of the programme, the approved research projects begin implementing the research described in their proposal. In this stage, TD processes of knowledge co-production are implemented at the level of the individual projects. Researchers collaborate with the societal actors relevant to their specific project questions. Our study showed that implementation of TD research can be very challenging. For example, progressing TD collaboration often requires adaptation of the research designs to respond to needs and perspectives of different disciplines and societal actors. Research funding programmes can substantially support the projects during this stage (see Stage 8).
6. *Joint agenda setting (Phase B, programme navigation)*. After the research projects have been selected, a joint agenda-setting stage is needed to *re*define problems and goals (Phase A) previously defined independently by different actors (e.g. individual research projects, on the one hand, and the steering committee, on the other). To establish a firm basis for engagement of individual projects in the TD synthesis process, it is important to

align or realign the programme's scientific topics and societal transformation goals with the topics and goals set out in the approved research projects. It is also necessary to agree on organization of the TD synthesis process itself, including the involvement of stakeholders. Moreover, it ideally provides an initial opportunity for individual projects to begin taking ownership of programme goals.

This stage is often overlooked in official programme plans. However, our research shows that when this stage is not taken seriously and goals are mainly defined by the steering team of a given TD research programme, frictions can emerge in later phases of the programme and/or programme results may be deemed illegitimate for overlooking the normative or practical concerns of societal actors. One example of how this stage can be designed are the workshops that were organized at the start of the NCCR North–South programme, in which researchers and societal actors jointly identified the main problem areas to be addressed by the different research teams (Wiesmann et al. 2011).

7. *Networking and synthesis (Phase B, programme navigation)*. Networking and synthesis activities follow the stage of joint agenda setting. In this stage, insights generated by individual research projects are brought together and project members exchange knowledge. It may be regarded as the core processes of TD co-production of knowledge at the programme level. All the programme representatives involved in our study stated that designing and shaping these TD processes at the programme level is very challenging, since it requires facilitation of TD collaboration between heterogeneous individual research projects and societal actors from different levels. They reported that interaction events not considered meaningful by participants are typically not attended or are subject to criticism. They also reported that shaping TD processes requires particular expertise and authority.

   Based on these insights, group members concluded that TD programmes should: (1) elaborate sound TD methodological frameworks in the programme preparation and joint agenda-setting stage, enabling all researchers and societal actors to jointly agree on the themes and processes of TD collaboration; and, (2) that these processes should be implemented and facilitated by experienced TD specialists. The frameworks must outline promising sequences of TD interactions and assign roles to involved actors that the latter consider meaningful, for example, by gaining new insights or clearly seeing that their individual contribution is important and shapes the pathway towards jointly set goals.
8. *Interactions with participating projects (internal communication, training, and monitoring) (Phases B–C, project support)*. Supportive interactions with participating projects—including internal communication, training, and monitoring—is an ongoing task (see also Defila et al. 2006; Lyall et al. 2013). It can range from providing clarifying information about basic requirements and offering targeted trainings—e.g. for early career scientists—to setting up adequate monitoring systems for evaluation of individual project performances. Ideally, in a TD research programme, these activities are optimized to support the TD work of individual research projects as effectively as possible.

   Our study revealed the following two crucial elements: (1) Support researchers in developing and applying knowledge, skills, and competences of TD collaboration. TD competences such as fluency in suitable methods for TD knowledge production or possession of strong social and communicative skills are indispensable to the design and facilitation of fruitful TD research (Herweg et al. 2012; Wiek et al. 2011). However, these skills and competences are seldom taught in typical academic curricula. As a consequence, many researchers involved in our TD research programmes have only limited knowledge and experience regarding TD. They use the term 'transdisciplinarity' in their proposals to respond to the programme calls, but their respective competences and creativity are restricted. To tackle this situation, TD research programmes must find ways of supporting researchers in developing and applying the required knowledge, skills, and competences. One mentioned option is to organize training sessions to familiarize applicants with the methods and requirements of TD research. Subsequently, participating projects can be given access to TD advice, training courses, or peer knowledge-exchange events about integrative methods and communication skills. Annual reporting could be systematically employed on behalf of formative evaluation and provision of feedbacks regarding TD progress—preferably including face-to-face meetings.

   (2) Demand and reward TD, transformation-oriented working modes: Since TD competences are not mainstream in academia, any research programme aiming to foster TD research must explicitly demand TD designs and processes from the project applicants. This means that the requirements of TD work must be clearly communicated and that implementation of these designs and methods must be an integral part of the annual reporting. If TD designs and efforts appear insufficient, the programme should ask the projects to make improvements. At the same time, it is equally important to reward TD efforts. Rewarding of TD efforts should begin at the moment of project selection and continue through the realization of successful TD processes and outcomes. In both cases, it is key that not only scientific publications are counted, but also outcomes that (are likely to) have a transformative impact on society (see Step 9). Also, rewarding TD efforts implies to allow flexibility if ongoing TD collaborations require adaptations of the TD research designs.
9. *External communication and transformations (Phase C, programme navigation / implementation of projects)*. In a TD research programme, this stage goes beyond classic activities of knowledge transfer such as when research results are communicated to society in a one-way process. It involves more diverse and collaborative forms of interaction such as knowledge exchange, joint learning, and transformative practices (Lang et al. 2012; Mitchell et al. 2015; Roux et al. 2006). Communication and implementation activities usually intensify in the second half of a given programme, and may occur at the level of individual projects and/or the overall programme.

   Three modes of promising communication and transformation-oriented activities could be identified: (1) Generation of targeted knowledge products for science and society belongs to the most widespread contributions of our TD research funding programmes. Knowledge products included leaflets, reports, maps, software programs, decision-making tools, or radio/TV broadcasts. The research showed that knowledge products were especially valued by societal actors when they addressed a knowledge gap of their concern and when the products contained the right level of detail. In one case, for example, hydropower companies and government representatives

were eager to know how the availability of water resources might change under climate change conditions and how they should adapt their management practices. In this case, it proved highly useful to generate and supply them with graphs visualizing the possible future evolution of available water resources. At the end of the programme, standardized metrics can be used with relative ease to evaluate the generation of targeted knowledge products.

(2) Facilitate learning processes on technical, normative, and practical aspects. Another regularly mentioned key contribution of TD research funding programmes is enhancement of mutual learning *processes* among researchers and other societal actors. As the diverse societal actors involved in a societal challenge may have differing problem perspectives and priorities, merely identifying and provisioning 'scientific facts' often is not enough to support societal transformations. In many cases, the facts may be contested or may be difficult to translate into practical actions capable of addressing the challenge under scrutiny. In the cases we investigated, for example, this came up in relation to questions about what a 'just' (i.e. fair) water governance system would look like and what the management alternatives might be. In such situations, one important societal goal—as aptly put by Mitchell et al. (2015)—may be to facilitate emergence of 'new perspectives, new orientations, new strategies, and new tools—seeing and doing things differently as a result of their experience of TD research'.

TD research programmes can foster this outcome through the creation of spaces for mutual learning between researchers and various societal actors to reflect on their diverse problem framings, normative assumptions, and the significance of new knowledge for practical actions capable of addressing the societal challenge. Spaces for mutual learning can be created through careful organization and facilitation of workshops, field trips, dialogue events, and informal encounters, as well as through participation in events organized by societal actors (e.g. policy dialogues). The synthesis stage of a given programme is also a particularly suitable stage to emphasize the facilitation of mutual learning.

(3) Strive to improve societal problems. Many of the interviewed programme participants suggested that improving societal problems represents the gold standard of TD research. Depending on the specific problem context, improvements were seen as any of the following: tangible changes in structural obstacles, institutional settings, and management strategies or practices; shifts in policy or societal discourses; spread of more inclusive and participatory forms of collective decision-making; realization of organizational innovations or adaptations; dissemination of technologies or application of decision-making tools. However, other than simply presenting research results, they were often not very explicit about how research can contribute to such improvements. In many cases, research programmes do not last long enough to oversee effective translation of innovative research insights into societal transformations.

As a consequence, group members recommended that TD research programmes more carefully investigate: how changes in the targeted societal field can be brought about; how the research programme can contribute to such changes; and what must be achieved before the programme concludes so that societal transformations might continue to unfold even without the direct involvement of the programme. One solution explored by two participating research programmes was to fund small pilot projects that specifically implement transformative activities as an integral part of the overall programme. Another possible solution mentioned involved more careful planning of follow-up processes and interfaces (e.g. patronage) between the research programme and subsequent societal efforts.

10. *Programme conclusion and impact evaluation (Phase C, programme navigation)*. The conclusion of a research programme usually means wrapping up all its activities and communicating its final results. However, contributions to societal transformation often require more time to unfold. Thus, in many cases, follow-up activities are needed to effectively (re-)integrate TD research results into societal practice. Therefore, group members stated that the concluding stage of TD research programmes should also include the handover of responsibility to other suitable actors/organizations capable of carrying on the initiated work as needed.

Moreover, evaluation of scientific and societal impact should be part of all large research programmes to assess their performance and learn for future programme designs (Lang et al. 2012) . Impact evaluation should cover the activities of individual participating projects, but also the programme as a whole. Ideally, evaluations will be carried out at different points in time to capture both short- and long-term impacts emerging from the TD research programme. Finally, the relevant TD processes and emerging pathways to societal transformation should also be explicitly addressed in the evaluation.

4. Discussion and concluding remarks

We began this article by discussing available knowledge on successful TD research—including its contributions to societal change—and we identified a major research gap in terms of knowledge about the structures and management of corresponding funding programmes. An increasing number of research funding programmes call for TD co-production of knowledge. Further, many researchers agree that TD research funding programmes require different structures and management than those oriented towards basic (disciplinary) research. However, knowledge is limited as to how funding programmes can effectively foster TD processes in their programme implementation.

To improve the potential of these programmes to foster societal transformations via TD research, we developed a programme model that shows the key activity levels and stages relevant to implementation according to a TD approach. To our knowledge, it is the first model that unpacks and systematizes relevant programme activities and stages in this way. The model demonstrates how the TD research of participating projects is linked to other programme activities—namely project support and programme navigation—and how TD requirements must already be considered when developing the programme call and project-selection procedures, and maintained consistently up to and including the programme conclusion and impact evaluation. The participating programme representatives highlighted our model's potential as tool for helping plan and implement future TD programmes in a more anticipatory and coherent way.

Our TD research process centred on one well-researched programme as a case study, enabling us to examine a rich evidence base on behalf of the preliminary structuring of our model. Next, comparing the experiences of three other (less deeply investigated) programmes with our first-draft model enabled us to verify and

reconceptualise our initial findings, taking into account other programme contexts and implementation strategies. Participatory modelling with TD experts and actors involved in TD research funding programmes enabled us to further integrate wider TD experiences and to generate actionable new knowledge.

Based on our discussions with the programme representatives, we believe that reflexive application of the model by programme steering and management staff has the potential to improve the overall performance of programmes. The model tackles issues from a holistic perspective, taking into account relationships between different programme stages (e.g. project selection, the research quality of participating projects, and synthesis building). Our generic model might also be useful for the design and shaping of *disciplinary* and *interdisciplinary* funding programmes, particularly those aiming to generate knowledge that is directly applicable or otherwise relevant to society. In these cases, knowledge will be mainly produced through disciplinary and interdisciplinary approaches, but equal importance will be attached to thoroughly designing the programme call (including clear reference to societal goals to be addressed), accurately selecting the projects to match these goals, and carefully facilitating synthesis processes. Moreover, interactions with key societal actors may also be incorporated to identify relevant problems, ensure the right questions, and consider the needs of the targeted actors. However, though our 10 stages provide a useful starting point, our specific design recommendations may not be relevant for 'classical' research funding programmes. For example, while purely disciplinary applicant teams also require clear information from funding programmes (in stage 3), they generally share key concepts/methods and consequently do not require additional time for joint definition of problems and goals.

Moreover, we see significant potential to address key challenges frequently mentioned in the literature on TD research projects—such as insufficient time, insufficient competences, or participation fatigue (Defila et al. 2006; Lang et al. 2012; Leach et al. 2010; Renner et al. 2013)—particularly by applying the group members experiences of fruitful practices and ideas for improvements. For example, a programme can create more suitable framework conditions for implementation of TD research by allowing project leaders to reframe research goals based on interactions with societal actors, thereby making the goals more meaningful for them. Further, more suitable framework conditions can be created through funding of experienced staff responsible for actor engagement and knowledge integration, thereby ensuring high quality engagement processes. However, other frequently mentioned challenges are more difficult to address to the extent needed. For example, while the design of favourable reward systems is key for participating projects, as long as the broader science policy context mainly rewards relatively narrow disciplinary excellence, it will remain difficult for young researchers to invest in TD research (Kueffer et al. 2012; Rhoten and Parker 2004).

Another possible limitation of our work is its contextual nature: our insights were generated based on the specific experiences of four Swiss research funding programmes. The model and design recommendations therefore heavily depend on the challenges and potentials experienced in these particular programmes. However, as our identified models are rather generic, we believe that they are also relevant for other national and international funding programmes. The challenges of TD mentioned in our introduction section draw on many different countries and programme/project stages (e.g. programme development, proposal writing, project selection), and may very well be relevant in the majority of research funding programmes. Nevertheless, feasible ways of practically addressing these challenges in different stages could vary considerably in different contexts (e.g. depending on existing funding schemes; available financial resources; the experience and TD competences of programme managers, researchers, and societal actors; and science cultures). As a consequence, additional stages or alternative implementation pathways might be needed in different contexts. Based on these reflections, we conclude that the presented generic model could become an orientation tool for TD research funding programmes. At the same time, we see a need for additional research to shed light on the following: (1) the extent to which our developed model can be usefully applied to shape the design and implementation of TD research funding programmes in practice; (2) what pathways show promise for implementation of the identified stages in distinct contexts; and, (3) with respect to societal transformation, how participating or targeted societal actors perceive the collaboration and achieved impacts. Therefore, in a next step, studies should be initiated that systematically compare different pathways for funding programmes to facilitate TD research, taking into account societal actors' perspectives. This will further improve identification of good practices for use in designing and implementing TD funding programmes.

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Appendix 1
Details of workshop organization

	Agenda	Main outcomes
Workshop 1	1. Round table 2. Presentation and discussion of general project ideas, incl. goals of the learning group 3. Exchange on three questions (small groups, plenary): a. What expectations do the participants have of the learning group? b. What is needed for more efficient TD research? c. What knowledge gaps are there? 4. Discussion of possible in-depth case studies (plenary) 5. Joint lunch	1. Participants got to know each other and the project 2. The real-world problem was reframed and the direction of the planned research adapted (from project to programme level) 3. Researchers were given mandate to conduct research on NRP 61
Workshop 2	1. Repetition of project presentation 2. Presentation about insights of the last workshop (plenary) 3. Presentation and discussion of existing model, design recommendation from the literature, and their application to NRP 61. 4. Participatory modelling (plenary and small groups). Discussed questions: a. What are key elements of a TD research funding programme? b. What potentials, challenges, and coping strategies are there? c. Which principles might guide implementation of TD research funding programmes? 5. Joint lunch	1. Basic features of a generic model for a TD research funding programme were identified 2. Design principles from the literature were critically discussed and other more adequate principles were suggested
Workshop 3	1. Presentation and discussion of the revised model (plenary) 2. Presentation and discussion of the revised design recommendations (plenary) 3. Joint lunch	1. Consensus on model and design recommendations

Appendix 2
Potentials, challenges, and coping strategies mentioned by the four TD-funding programmes

Potentials, challenges, and coping strategies related to implementation of the four TD funding programmes were discussed in all three workshops. These discussions were an important input to the modelling process and the development of the programme design recommendations.

Below, we present a summary of mentioned challenges and suggested coping strategies, according to the three programme Phases A–C:

Phase A: Establish a TD programme in a traditional science context. Ensure collaborative teams at the programme level: Integration of social sciences and humanities, as well as practitioners (e.g. advisory group) → Integration of advisory board in project selection. Development of coherent TD frameworks with no/few TD experts and practitioners involved (both are not foreseen in existing structure, e.g. steering committee). The phase of programme/project development is most important to the later success of the programme; but due to the principle of competitiveness, the programme can only communicate requirements (no capacity building, advisory support, etc.) → rethink options for TD trainings. Communicate clearly TD requirements and options → ensure clarity regarding requirements in each phase (e.g. that projects will need to contribute to programme synthesis; how much money can be requested for stakeholder engagement; that experienced researchers must be assigned for stakeholder collaboration). Resources and capacities needed for joint definition of problems and goals in proposal writing phase→Enabling a joint problem- and goal-definition phase (e.g. between pre- and full-proposal, additional financing). Resources and capacities needed for joint definition of methodological approach regarding TD at programme level/synthesis process → joint understanding of TD research required and time budget → development of a methodological framework (e.g. at an initial workshop).

Phase B: Maintain coherence between programme goals and selected projects → consider during project selection; start synthesis process early. Integrate practitioners and policymakers at the programme level → give advisory board a more active role. Govern a TD programme with limited TD expertise → include TD experts on equal footing. Facilitate TD in a programme where research projects are largely independent units →More systematic inclusion of TD in annual reporting (incl. feedbacks) → Institutionalize structures for specific advice as part of formative evaluation → systematic capacity building and knowledge exchange (summer schools, training courses). Many researchers have limited experience and motivation for TD →same as above → reward mechanisms for TD efforts. Multiple understandings of TD (among researchers and in steering committees) → Clear communication of the programme's TD understanding, but openness to dialogue and multiple perspectives → Spaces for struggling for joint understanding, particularly regarding defining joint actions. TD processes can be messy, complex, and include social conflicts → Conduct formative evaluation →

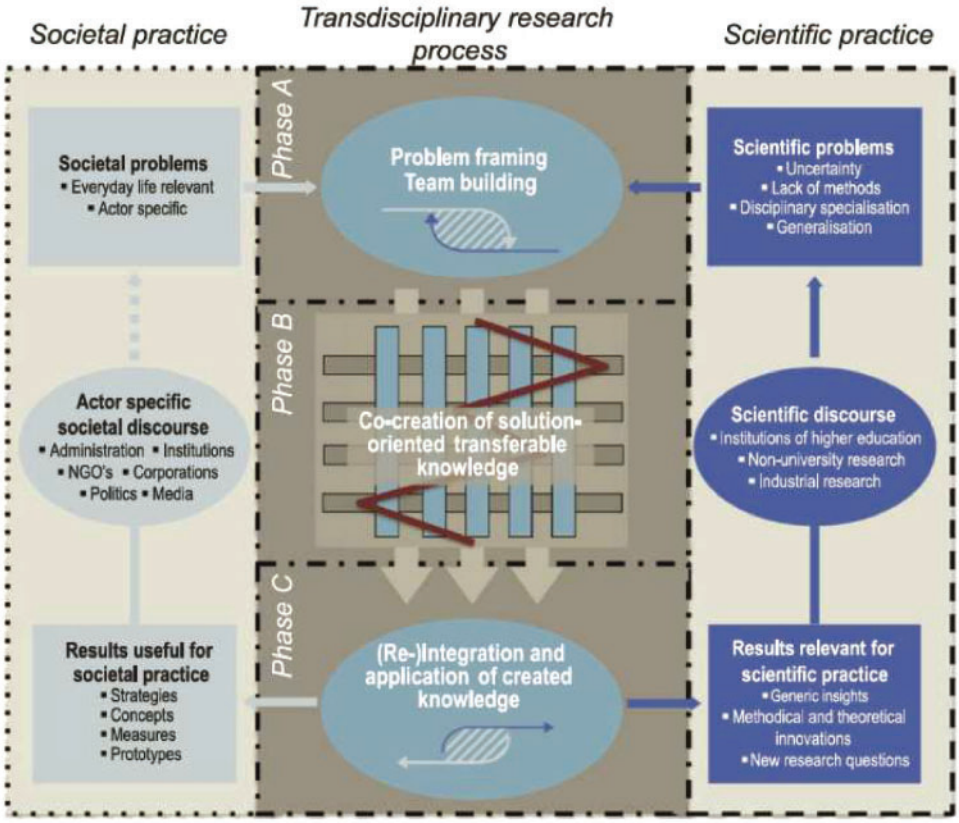
Sound process management, conflict management

Phase C: Accountability to academia and society can be challenging → mixed teams, including practitioners, communication experts, and researchers not aiming for an academic career (not only PhDs). Limited impacts towards real-world transformations → same as above → Realistic goals, what can science achieve? (between pure knowledge provision and 'solutionism'). Establish *Trägerschaften*. Limited evaluations. (Some) practitioners would prefer to get suitable knowledge without being integrated. Short timeframes, lack of organizations that fund 'intermediary' projects between science and implementation (only exists for marketable innovations, but not social innovations)→ enabling of follow-up processes (like r4d programme), project extensions to enable bringing results to fruition. Different conditions for institutionalizing TD in North–South context

Appendix 3
Steps and intermediary results of the model-building process

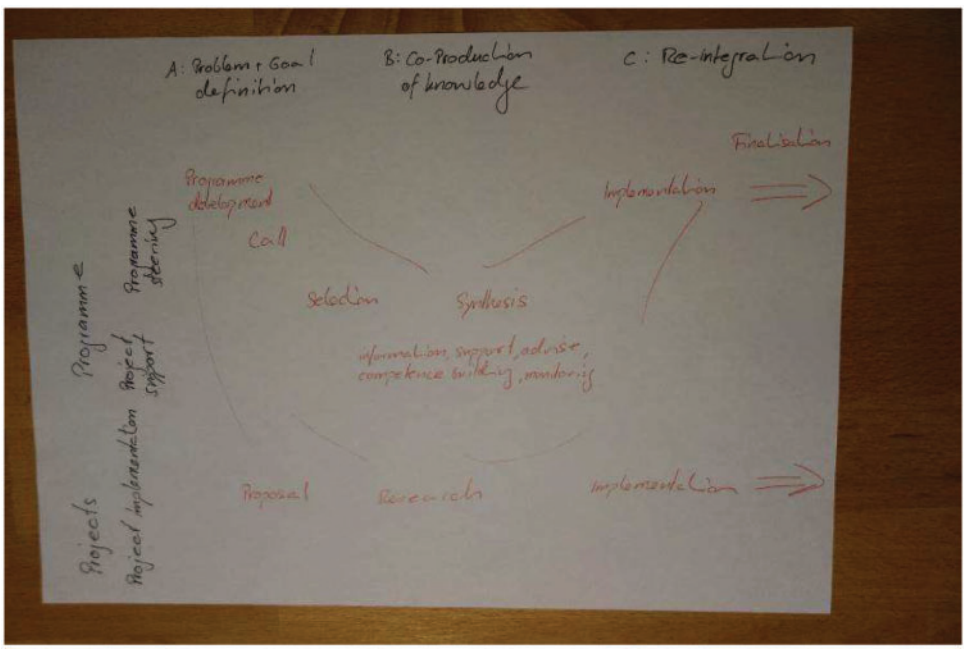
Discussion of a generic model of TD research from the literature

Lang et al. (2012) model of an ideal-typical TD research process served as a starting point. Critical questions raised by the group participants in the second workshop included the following: With a TD research funding programme, who should be involved in the joint problem framing (the programme initiators, the steering committee, the individual research projects, or all together)? What is considered co-production of knowledge (research in participating projects, synthesis)? How can the iterative nature of the three phases be dealt with? The participants concluded that the Lang et al., model (below) must be adapted for TD research funding programmes.



First version of the TD programme model

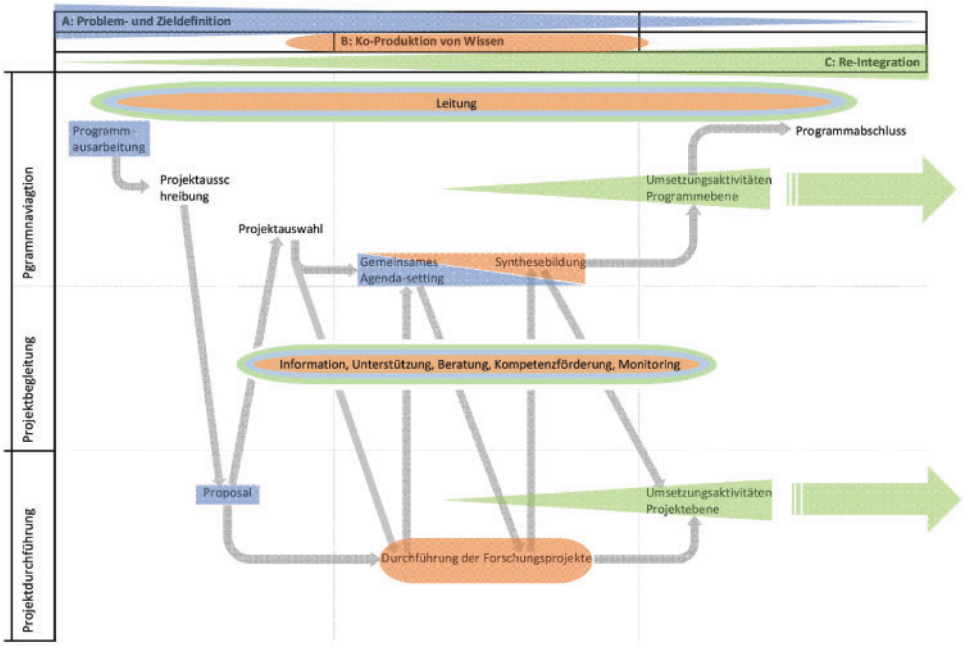
The adapted model was sketched by the co-authors after the second workshop. The three Phases (A–C) were based on the Lang et al. model (above); differentiation according programme activities; first ideas for stages from workshop discussions; and analysis of NRP 61.



Second version of the TD programme model

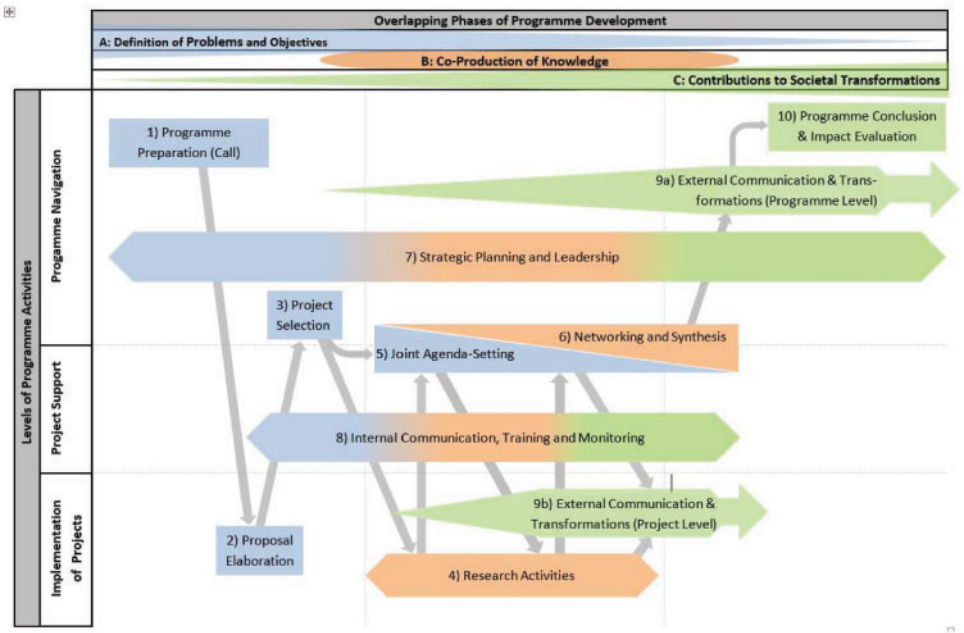
(continued)

This version was created by the co-authors based on further reflection regarding 'moments' that hindered or fostered TD collaborations in NRP 61. This model is more formalized and includes further steps such as *leadership* ('Leitung') and *joint agenda setting*, links between the stages and colour coding according to the phases. Terms were changed to better capture the right meaning, e.g. *programme steering* was replaced with *programme navigation*. This version was presented at the third workshop. The participants discussed it against the background of the four different TD research funding programmes. Overall, they stated it adequately represented key stages of all four programmes, but they argued in favour of refining and repositioning certain elements.



Third version

This version was developed after the third workshop and included a key requested change: the *leadership* stage was moved to the middle to represent its position at the centre of the programme rather than above it. Additionally, some stages were combined to reflect programmes with other procedures, and other elements such as *impact evaluation* and *transformation* were added.



Fourth and final version

The version presented in the article was further refined in the article-writing process. The *planning and leadership* stage was skipped altogether as it become clear that all other stages in fact encompass it. The *internal communication, training, and monitoring* stage was divided in two to strengthen its importance during Phase A. Both changes were consistent with previous discussions in the group.